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Relationship of fitness to performance in a winter mountain warfare environment

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THE RELATIONSHIP OF FITNESS TO PERFORMANCE IN A WINTER MOUNTAIN WARFARE ENVIRONMENT

By

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Two Hundred Twelve U.S. Marines were randomly selected to participate in this study investigating the relationships between fitness variables and work performance. The fitness measures (3-mile run, situps, pullups, pullups with a 30-pound pack, 150-yard uphill dash, longjump, lean body weight (LBW), and percentage Fat) were compared to field performance times through simple and multiple correlational analyses. The 3-mile run, situps, 150-yard dash, and LBW were all significantly correlated to field task performance ($r= .61, -.58, .42, -.39$ respectively $p<.05$). Multiple correlations produced three test batteries with correlations of: $R= .49, .48,$ and $.48$ respectively.

The results of this study indicate that the Marine Corps physical fitness test (PFT; 3-mile run, situps, pullups), the 150-yard dash, and LBW are all significant predictors of performance in the high altitude cold weather environment. The PFT is a valid indicator of physical readiness to perform in this environment.

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E.A.K.

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CHAPTER I

The Problem

INTRODUCTION

Since the early 1970's the U.S. Marine Corps has been using a physical fitness test (PFT), developed by naval medical scientists, as its primary measure of fitness (12). Consisting of a 3-mile run, situps, and pullups/chinups, the PFT has been used as a training event and as a fitness gauge.

A recent Department of Defense Directive (21) has ordered each branch of the military to evaluate the appropriateness of their training programs and to make changes if necessary. Upon reviewing the PFT, the Marine Corps realized that the criterion-related validity, or relationship to combat task performance, had not been established. Noting this weakness, Headquarters, Marine Corps contracted with the Institute of Human Performance (IHP), Langley Park, Maryland to determine the validity of the PFT as a predictor of combat readiness. Additionally, a test battery of fitness measures (longjump, 150-yard - 5% grade hilldash, pullups with 30-pound pack, and antropometric measures) are being studied for possible inclusion in the Marine Corps PFT.

This study, a portion of the IHP project, is based upon a task analysis study published by IHP in 1982 (1). For this study IHP "gathered descriptive and objective information about the types of physical performance tasks encountered by Marine infantrymen" in the winter mountain warfare environment. Sustained marching with heavy gear was identified as the overriding physical task of Marines operating in high altitude, cold weather environments. The task analysis has served as the framework for construction of this study.

Utilization of screening tests such as those described in this review could improve performance and reduce the risk of overstrain injuries. In the case of the Marine Corps, valid predictors of performance in specific combat environments could help guide training and allocation of troops, and could lead to more efficient training programs.

THE PROBLEM AND ITS SETTING

Statement of the Problem

The purpose of this study was to investigate whether performance on the Marine Corps PFT or other selected tests allow prediction of performance in actual field tasks.

A subproblem of this study was to investigate the relationships between Lean Body Weight (LBW), percent fat and field performance.

The Hypotheses

1. None of the fitness variables (3-mile run, situps, pullups/chinups, longjump, hilldash, pullups with a pack, LBW, percent fat), will be significant predictors when individually correlated to field performance.

2. A multiple correlational analysis with selected combinations of the fitness variables will be predictive of performance in the winter mountain warfare scenario.

Delimitations

1. The study was limited to predicting performance in simulated combat conditions, and does not attempt to predict the success of Marines in actual combat situations.

2. This study is limited to predicting performance only in the winter mountain warfare environment.

3. The study will be limited to the members of the U.S. Marine Corps 2nd Battalion, 7th Marines (2/7) and the 3rd Battalion, 5th Marines (3/5) during training at the Mountain Warfare Training Center (MWTC) in the winter of 1985. However, the sample is large enough to allow inferences to be made to the entire Marine Corps.

Abbreviations and Definitions

LBW is the abbreviation used for Lean Body Weight. This is a measure of a person's muscle and skeletal weight. (Body weight excluding fat weight.)

MOS is the abbreviation of word for Military Occupational Specialty. An MOS is a person's military job description.

PFT is the abbreviation used for Physical Fitness Test. The Marine Corp's PFT consists of a 3-mile run and the maximum number of pullups/chinups a person can do as well as the maximum number of situps one can do in 2 minutes.

The PFT is worth a maximum of 300 points. There are some scoring modifications with age, but, our average Marine is given 100 points for the run and looses points for each second he is off the 18-minute target time. Each situp up to 60 is worth 1 point, beyond 60 situps each repetition is worth 2 points. Each pullup/chinup adds 5 points to the cumulative score.

Percent fat: indicative of the portion of a person's body (by weight) consisting of fat.

Test Battery: a set of laboratory and field tests being studied for possible inclusion in the PFT. The test battery included: a 150-yard, 5% grade hill dash, a longjump, chinups with a 30-pound pack, and anthropometric data to determine lean body weight and percent fat.

Assumptions

1. The PFT score reflects a maximal effort by the individual Marine.

2. Performance scores on the winter warfare test scenario are reflective of a maximal effort by the individual.

REVIEW OF THE RELATED LITERATURE

Research Related Methodology

Historical Overview

The earliest known military fitness testing was done in ancient Greece (1), however, the first published analysis on a modern force appears to be a study done by Brezina and Kolmer in 1912 (2). This research is significant because it is an early example of a task analysis similar in context to the one described in this manuscript.

Current Studies

In 1978 the Federal government issued a report outlining Uniform Guidelines On Employee Selection Procedures (3). This report, written through the combined efforts of The Department of Labor, Office of Personnel Management, Equal Employment Opportunity Commission, Department of Justice and the Department of the Treasury, outlines methods and procedures for the development of pre-employment tests. The guidelines require job-related performance tests to be validated in one of several ways, including construct and criterion-related validity studies.

To prove construct validity, data must be presented to show that the "test procedure measures the degree to which candidates have identifiable characteristics that have been determined to be important in successful performance of the job for which they are being evaluated (6)". Construct related tests do not necessarily need to resemble the tasks people are being screened for, therefore, these tests often lack face validity for the subjects taking part in the testing. The abstract nature of this type of test can result in low motivation on the part of the subjects, which can lead to poor task performance.

Another common and perhaps more realistic way of establishing validity is through a criterion-related study. A criterion-related test duplicates the actual tasks required for the job. This type of study has the advantage of a high degree of face validity, presenting the subjects with a clear relationship between the test and the job. To prove criterion-related validity, the federal guidelines require that data be presented showing that the selection procedure is predictive of or significantly correlated to job performance (6).

> "Generally a selection procedure is considered related to the criterion. . .when the relationship between performance on the procedure (test) and performance on the criterion measure (job) is statistically significant at the .05 level of significance (3)".

It was the consensus of the test team conducting the Marine performance study that criterion-related validity would be the method of choice. Therefore, the test should be constructed to closely resemble the actual tasks required by Marine infantry men in winter mountain warfare conditions.

Following these guidelines, studies have been conducted in the armed forces, the Forest Service, and in other sectors of public life. Each of these groups have used task analysis studies to identify common tasks and fitness tests related to the tasks.

One example is a study done by the U.S. Army Research Institute of Environmental Medicine (USRIEM), which surveyed tasks performed and identified fitness requirements for each MOS (4). The Army has identified five MOS clusters which have different fitness requirements. New recruits are screened through fitness testing and then directed towards a suitable MOS. Other branches of the armed forces are using similar procedures in developing fitness tests suited to their own task demands. The Air Force is currently using an "X-Factor" test in which recruits move weights similar to aircraft weapon systems (5). The Army and Air Force projects are similar in procedure to what this study proposes, however, because of the different tasks encountered, the energy demands and fitness requirements are quite different.

In 1982 Sharkey, et al. (6) conducted a study to determine the relationship between fitness variables and work performance in forest fire suppression crews. That study proposed to develop a test to determine a person's fitness for fighting forest fires. One hundred twenty subjects of both sexes and several ethnic backgrounds took part in the study. Fitness measures included: chinups, situps, pushups, a step test, body fat measures, measures of arm and leg strength. The subjects then performed a field test with actual fire fighting tasks including: fire line construction, shoveling dirt, a hose lay, a charged hose pull and a load carrying task. Correlations between the tasks showed that several items in the test battery including: chinups plus weight, pushups, situps, as well as arm strength, body fat and lean body weight were all good predictors of total work performance (r= -.63, -.64, -.50, -.68, -.63, -.61 respectively).

Two other studies are mentioned here because they are related to the procedures employed in the previous studies. These studies follow the trend toward the use of job-related tasks in screening tests. They include a test designed by Miller (7) which helps select police recruits. In Miller's test, recruits must sprint, push a car, carry a body, run an obstacle course and run a distance event before being considered for employment. The final study is a study which developed an entry exam for structural firefighters (8). This study, done by Davis, et al. established several easy-to-administer tests which have been shown to be predictive of actual performances. Dotson and co-workers correlated performance on selected tests to performance in actual work tasks. Their tests included: pushups, situps, chinups, standing broad jump, grip strength, flexibility tests, oxygen consumption tests and blood pressure responses. The criterion tasks included: ladder work, standpipe section carry, hose pulling, simulated rescue carry and simulated chopping. These researchers concluded that a high aerobic capacity and resistance to fatigue were related to work performance. In this study lean body weight, and percent fat were found to be good predictors of work performance.

Each of these studies have related measures of fitness to performance of job-related taxes. The procedure allows an objective approach to the development of valid, job-related tests. Each of these studies have met guidelines established by the Federal Government for the development of employee screening tests.

Body Composition and Work Performance

The health risks associated with obesity have long been known. This was clearly established in 1959 with the Build and Blood Pressure Study (16). This study and others have linked obesity with such ailments as atherosclerosis, hypertension, diabetes, cirrhosis, and increased mortality particularly among young people (16, 33, 34). Other researchers have supported these findings and reported up to a 79% increased risk of death (above standard risk) for markedly overweight individuals (17, 35).

A person's body type not only influences the health of the individual, but also influences physical capabilities.

Some researchers have found it helpful to be able to classify body builds according to somatotypes which allow relationships between body type and work capacity to be drawn. Somatotyping indicates the relative degree of fatness and muscularity a particular body possesses. Studies examining these relationships have come up with the following generalizations on physical performance and somatotypes (18):

> . . .the endomorphic individual is characterized by an excessive amount of weight which is a limiting factor in the performance of most skills. The 'dead weight' which the endomorphic individual carries around with him is a serious handicap. Second, the ectomorphic individual is muscularly weak, relatively speaking, and subject to injury. . .the mesomorphic individual is characterized by physical ruggedness and strength that, without question, are conducive to excellent physical performance.

The usefulness of somatotyping does have its limitations, however, and newer techniques for assessing body composition have become the norm. For example, determination of body fat and lean body weight has become almost routine when considering performance parameters. Moreover, recent research has shown a statistical relationship between body fat, lean body weight and work capacity (6, 20, 19). Today, many researchers consider these to be important variables in performance prediction. These studies have shown that a higher lean body weight or percent lean body weight is correlated to higher muscle mass and maximal oxygen consumption. A high maximal oxygen consumption is indicative of a high work capacity.

In conclusion, all of the cited studies agree that an excess body fat hinders work performance. Furthermore, most authorities agree that excess body fat poses significant health risks. The studies most relevant to this investigation are those by Sharkey (6) and Dotson (20) which have found significant correlations between work capacity and lean body weight. These two studies are most applicable to the Marine population because of the similarities in the physiological demands of the tasks and the ages of the populations.

The Marine Corps Physical Fitness Test (PFT)

In the late 1960's the Marine Corps learned that, in general, their men had poor fitness levels and very low life expectancies (11). Consequently they sought to initiate training programs and a physical fitness test. They wished to develop a test which would indicate fitness levels and be long enough to provide a training effect.

Due to the rigors of combat, it was determined that the fitness level of a Marine should be above the minimum level required for good health (12). Furthermore, the test developers felt that for a Marine to perform effectively, he must possess strength and endurance in the muscles of the upper body and the trunk. He must also have cardiovascular endurance.

The PFT, which was developed for use by the Marine Corps, is an easy-to-administer three-part test. The three measures selected for use include: pullups or chinups as an indicator of upper body endurance, bent knee situps as a measure of trunk endurance, and a three-mile run as a measure of cardiovascular endurance. These particular items were selected because of their simplicity of test administration and the high values reported in the literature for reliability and validity (12, 13).

The three-mile run used in the PFT is a modification of Cooper's 12-minute run (13). The modification recommended by the Naval Medical Field Research Lab (NMFRL), allows for a common end point for all participants and promotes the desired training effect (14). In its study, NMFRL found that a time of twenty-eight minutes (28) for a three-mile run was equivalent to a $\dot{V}O_2$ of 42.5 which Cooper labels "good" as an indicator of cardiovascular endurance. This $\dot{V}O_2$ was selected as the minimum acceptable score for a Marine running the three-mile course.

Performance norms for the chinup/pullup and the situp events were established from the current literature in Physical Education (15). The Marine Corps referenced the published norms and determined minimum acceptable performance scores. The minimum number of repetitive pullups/chinups for a Marine is three. The minimum number of situps performed in two minutes for a Marine under the age of 26 is forty. Marines over the age of 26 must do thirty-five situps in two minutes.

In summary, the NMFRL study has found that the PFT is a valid, objective, and reliable measure of muscular and cardiovascular endurance. The PFT does, however, have a limitation because the relation between PFT performance and actual field performance has not been established. This manuscript will attempt to show if a significant relationship exists between the test and simulated field tasks in the winter mountain warfare environment. If this relationship is not significant, modifications to the PFT will be suggested.

Test Battery

The task analysis which preceded this study; Physical Performance Tasks Required of U.S. Marines Operating in a High Altitude Cold Weather Environment, identified important and frequently performed activities. Based on this analysis IHP conducted a review of physical performance literature (10, 12, 13, 15, 27) and selected test battery items to be studied for possible inclusion in the Marine Corps PFT. These items, which were selected to compliment the performance parameters related to the PFT include; a 150-yard - 5% grade hilldash and a longjump test as two measures of anaerobic power and pullups with a 30-pound pack as a measure of arm and shoulder strength. These items and their relationships to the PFT and to the field performance tasks are discussed in a forthcoming section.

CHAPTER II

METHODOLOGY

Research Strategy

IHP conducted a task analysis in 1982 and identified the tasks required of Marine infantry men during winter maneuvers. The major tasks included: hiking or jogging on a snowpack, snowshoeing with heavy packs, pulling loaded sleds, digging fighting positions in the snow, and sprinting (e.g. to helicopters). Other tasks were also identified, but review by mountain warfare experts confirmed them as being of secondary importance.

Each of these tasks were analyzed to determine the specific fitness requirements involved. A review of the literature, performed by IHP, revealed a series of simple tests to measure these fitness parameters. These fitness tests or variables are referred to in this test as the test battery and are discussed in a forthcoming section. The critical tasks identified above were arranged into a field event and are the criterion measure for the purposes of this study.

The basic research design employed in developing this project closely resembles the protocols discussed in the review chapter. In particular, the methodology simulates the successful procedures which Sharkey (6) and Davis (8) have utilized with firefighters. These researchers and others have found that statistical correlations between highly specific criterion measures and simple fitness variables yield significant indicators of work potential.

Subject Selection

Approximately 212 Marines were randomly selected from battalions 2/7 and 3/5. This sample provided nearly 200 individual measures for each variable under consideration, thereby meeting guidelines established for drawing inferences to large populations, such as the U.S. Marine Corps. The computer-generated random selection assured representation of Marines with a variety of ranks, ages, job specialties, and fitness levels. Selected population demographics are presented in Table 1.

Battalions 2/7 and 3/5 were selected because they were considered to be representative of the Marine Corps (i.e., not a special force) and they were scheduled to be at MWTC during the test period. All participants in this study had spent nearly three weeks at MWTC prior to the test. During this three-week period, the subjects had been instructed in the use of snowshoes and other equipment, and they were acclimated to the test site altitude (7000 - 9000 ft.) and cold weather conditions.

The use of human subjects in this test has been reviewed and approved by Naval Health Research Center (NHRC). Each subject signed an informed consent form before taking part in this study.

Data Collection

Phase I

Marine Corps PFT and Test Battery

Phase I data were collected by the commanding officer and NHRC respectively, both parts of Phase I were done at sea level. The data collected included the PFT (time for the three-mile run, the maximum number of pullups/chinups, and the maximum number of situps performed in two minutes). Data were also recorded on the test battery (giving the time for the hilldash, the distance covered in the longjump, the number of chinups performed with a 30-pound pack as well as anthropometric measures).

PFT.

Prior to running the three-mile course, each Marine was instructed to pace himself to ensure completion, yet run as fast as possible. The results of the three-mile run, including the number of participants, the average score, the range, and the $\dot{V}O_2$ equivalents are presented in Table 2. The validity and reliability of the three-mile run as a measure of cardiorespiratory endurance must be inferred from similar tests such as the 12-minute run, which have reported correlation coefficients of .90 and .94, respectively (10).

To perform the situp portion of the PFT each Marine was assigned a partner to hold his feet and instructed to go through a full range of motion. Only the number of complete situps done in the two-minute period were recorded. Table 2 includes the results of the situp event. The use of situps as a measure of abdominal endurance has been shown to have a reliability coefficient between .70 and .94 (10). The validity has not been fully studied and has coefficient values near .35 (10).

The final portion of the PFT was the pullup/chinup event. For this test each Marine could grasp the bar as he chose; either with palms facing forward in a pullup position, or with palms facing the rear in the chinup position. A test assistant recorded the number of complete pullups/chinups performed. A complete pullup/chinup was one that began from fully extended arms and terminated with the chin going higher than the bar. Swinging the legs or "kipping" was not allowed. The performance data for this event is presented in Table 2. Pullups and chinups which indicate arm and shoulder endurance have a reliability of .93 and a validity of .64 (10).

Test Battery

Test battery data were collected by the NHRC staff in cooperation with the IHP test team. The fitness measures taken by NHRC included: a hilldash, a longjump, pullups with a 30-pound pack, and anthropometric data. The results of these events are presented in Table 3.

The task analysis which preceded this study suggested that leg power was necessary for efficient performance of critical tasks in the winter mountain warfare environment

(1). For example, snowshoeing and walking up steep grades in deep snow with heavy packs requires considerable leg power. The test team felt that an accurate assessment of this relationship could be established with a running event which was shorter and more intense than the three-mile run; a 150-yard 5 percent grade run was included to empirically determine the relationship of leg power to task performance. For this event each Marine was instructed to run as hard and as fast as possible. Time for the run was measured using a hand-held stopwatch. No information is available on the validity and reliability of the hilldash, however, the face validity of the test as a measure of anaerobic power and capacity is high, and the test is quite similar in intensity and duration to the 30-second Wingate Anaerobic Power test (32).

A standing longjump event was included as an additional measure of leg power. This simple and straightforward test allowed a second measure of anaerobic power to be correlated to work performance. This test required the subjects to stand with their toes on a reference line and then vigorously swing the arms forward while extending the legs. The horizontal distance each person jumped was obtained with a tape measure. The reliability of the longjump as an indicator of leg power is reported to be .96 while the validity has been determined to be .61 (25).

A chinup test with a 30-pound pack was included to see if upper body and shoulder strength was significantly related to work performance. The task analysis study indicated that many of the Marines' daily chores involved lifting and moving heavy objects such as food and ammunition boxes, water containers, and other basic supplies. It was felt that the pullup/chinup event in the PFT was more indicative of endurance and didn't discriminate relative degrees of strength in this population. In following the protocol established for the pullup/chinup event, only complete chinups were recorded, and to prevent kipping a second Marine was asked to stand in front of the one doing the work. The test was ended when a delay of more than one second occurred at any phase of the pullup. The use of chinups with a 30-pound pack has not been validated as an indicator of upper body strength, but a formula reported in the literature shows a good correlation between work done with chinups and total work performed (work done with chinups = number of chinups x weight lifted) (6).

The final portion of the Test Battery was the collection of anthropometric data by the NHRC staff. These data allowed estimates to be made of percent fat and of lean body weight. These parameters are of particular interest to this study because of their strong relationship to work performance reported in the literature (6, 8). The measures that were taken included height and weight, as well as neck and abdominal circumference. The weight of each Marine was obtained using a medical-quality upright balance equipped with a scale for measuring height. The neck and abdominal circumferences were obtained using a commercially available cloth measuring tape. These data were used in the formula of Wright, Dotson, and Davis (9) to estimate body fat and lean body weight. Because of the large sample (n = 200) this simple technique was chosen over other techniques such as skin fold measures or hydrostatic weighing. This formula has a validity of .86 with a standard of error of estimate of 3.65% (9). The reliability has not been determined, however, based on the simplicity of the technique, reliability should be high. The anthropometric data describing the Marine sample can be found in Table 1.

Phase II

Criterion Measures; the field test

Phase II data were collected by the field test team in the Sierra Mountains near MWTC. The sequential, multi-event test was conducted at Sardine Meadows (8800 - 9000 ft.). Figure 1 and 2 show the geographic location of the test site. The data collected in Phase II included heart rates for the entire scenario, the length of time to perform each event, and a measure of perceived exertion.

Field Test Development

Several weeks prior to the scheduled test period, a development team was assembled at the MWTC to establish protocols and to secure gear necessary for the event. Arrangements were made for tracked snow vehicles to pack the trails and for helicopters to transport equipment. A tent at the Sardine Meadow site provided an area for staging the gear used in the test and temporary living quarters. Other housing arrangements were maintained in a nearby town for the duration of the two month test period.

The test team included subject matter experts from a variety of disciplines including two exercise physiologists, a physician, a statistician, two experts in snow course preparation, a Naval medical aide, and two mountain warfare experts. The test team worked together for several days and developed a sequential field event which resembled a pentathlon. The field events replicated the work identified in IHP's task analysis and incorporated the five tasks considered to be of critical importance to a Marine in a winter mountain warfare environment. The five events selected were: running or jogging on the snow pack, snowshoeing with heavy loads, pulling loaded "AKHIO" sleds, digging fighting positions in the snow and sprinting short distances to resupply. Each course was carefully evaluated to ensure that choice of terrain, the duration of the event, and the physiological load on the subject closely simulated actual field conditions.

Prior to the actual testing period, several practice tests were conducted. These practice sessions, involving the development team members and Marine Corps volunteers, verified the test scenario as being an appropriate model for the criterion-related study. During this period Marine Corps volunteers were video-taped as they negotiated the field events. This video later served as an instructional aide to other participants by showing the purpose of the test, appropriate dress, require equipment, and performance expectations while taking part in the test. The video-taped instructions were verbally repeated to each subject prior to the event.

Field Test Protocol

To ensure similar test conditions for each subject, the trails were marked with colored flags and groomed regularly.

A typical test session involved a company of twenty men flown by helicopter from MWTC to the mountain test site. Each Marine came with his issued survival gear, winter clothing and weapon. The weapons, fitted with laser simulators, were used in a parallel study conducted by IHP to investigate the relationships between fitness, fatigue, and shooting accuracy. The weapons were also carried throughout the scenario to simulate actual combat situations. Upon arrival at Sardine Meadows, the Marines were randomly assigned starting numbers and equipped with a Quantum XL heart rate monitors. These portable, wrist watch instruments made by AMF, Inc. provided heart rate data collection for the entire scenario.

After completing the registration and telemetry preparations, Marines were sent out on the hard-packed snow course in five minute intervals. The first event was a 1.5-mile run in which each Marine was instructed to go quickly, yet save some energy for the more demanding tasks to follow. This event simulated rapid deployment techniques required on front line maneuvers. This course began near the tent, at the start area and followed a gradual downsloping trail to the east before turning and climbing a sustained grade to the northwest. From a point 120 feet above the start area, the trail returned to the base of the hill and led directly to the start/finish area. Test administrators at the start/finish area recorded the elapsed time taken by each Marine and set the heart monitors in a standby mode for a five-minute rest and rehydration period.

Following the rest and rehydration period the Marines began the second event, which required carrying a 50-pound pack while snowshoeing over hilly terrain. The snowshoe test simulated a common method of troop movement both in the technique and in the weights carried in the pack. This course began at the central start/finish area near the tent and crossed the meadow to the west where it began a long climb up the mountainside. The 1.75-mile trail climbed a total of 360 feet to a small plateau where it turned and followed a stream back to the meadow. Upon completion, times were recorded and the monitors set to standby.

The third event, which followed a 5-minute rest period, required each subject to pull a sled, known as an AKHIO, 1.75 miles on a relatively flat course. Each Marine wore snowshoes and pulled the 100-pound utility sled around a prepared course. This event simulated actual sled movements involving up to four men and loads exceeding 400 pounds. The trail used for this event began near the tent and climbed a gently sloping meadow to the south, before returning to the start/finish area. The time for the event was recorded and the heart monitor was attended to by the administrator.

A fighting hole dig was the fourth event in the scenario. This event required each subject to dig a four foot by five foot (4' x 5') hole in the snow using a small folding shovel called an entrenching or 'E' tool. Standardization of the work performed was achieved by having each Marine fill five 30-gallon garbage cans with snow. The time spent digging and the heart rates were recorded as in each of the other events.

The final event in the criterion-related study was a resupply dash requiring each subject to sprint 50 yards to reach two 45-pound water containers and to return with the water as quickly as possible. This event simulated the running and effort required when getting supplies from helicopters. This event was staged on a packed trail between the tent and the helicopter landing zone.

The field test was concluded by retrieving the heart rate monitors from each subject and by having the subjects fill out a questionnaire describing their levels of perceived exertion for each event.

Figure 1.

Geographical Location of MWTC and Field Test Site

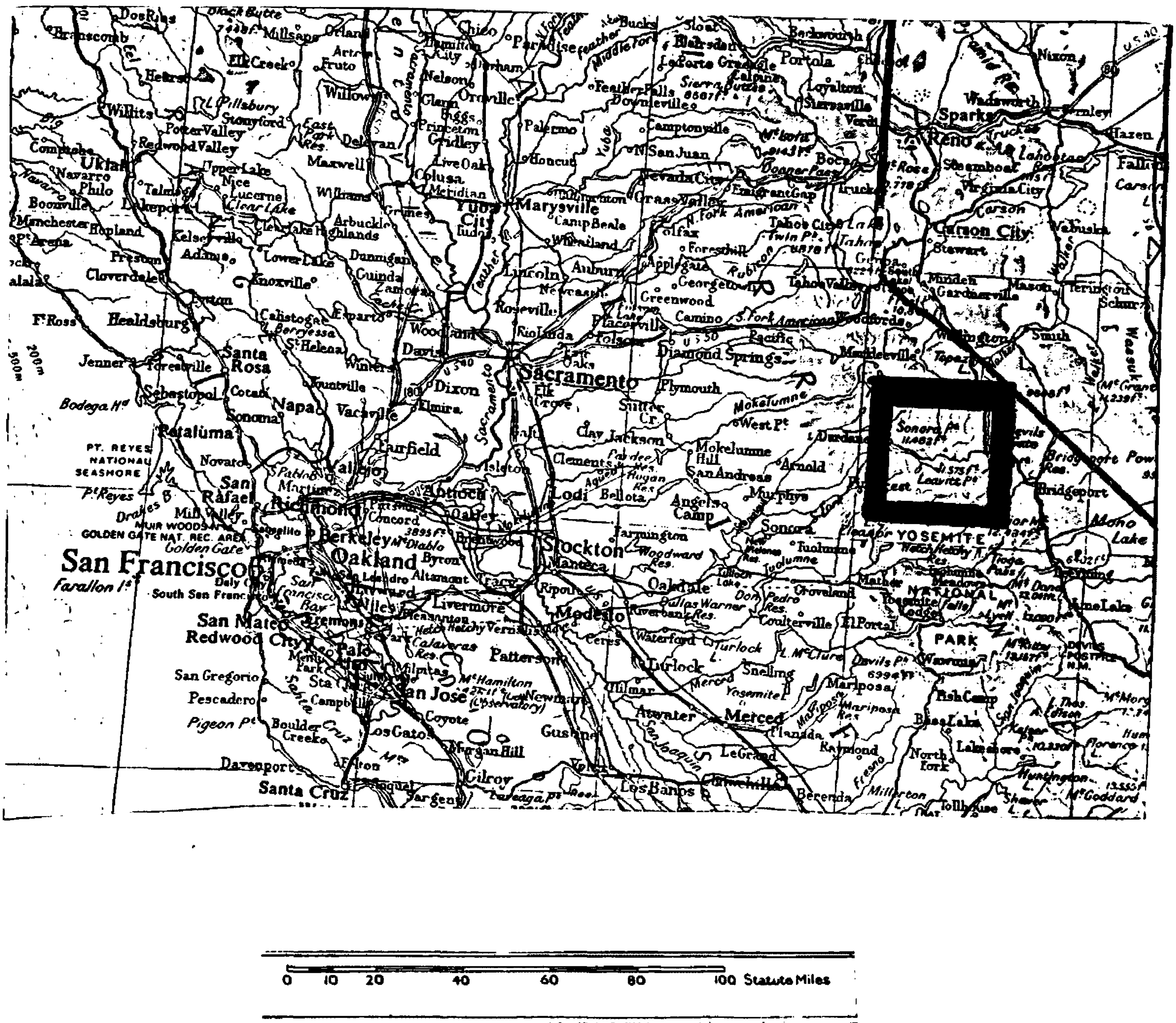
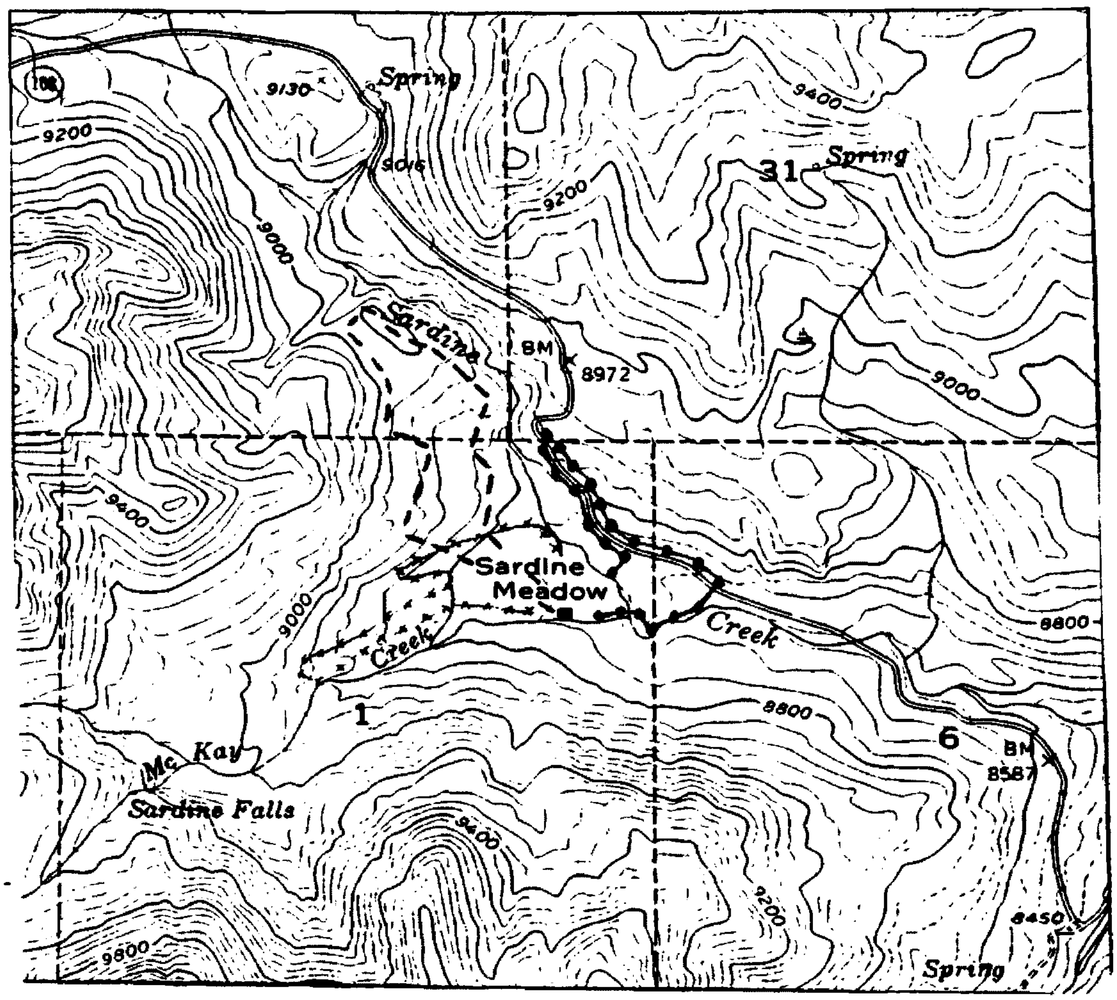


Figure 2.

Topographical Map Showing Field Test Site



Start/Finish Area ■

VB Run •—•—•

Snowshoe/Pack Hike - - -

Akhio Sled Pull ×—×—×

CHAPTER III

RESULTS AND DISCUSSION

Data Analysis

Data collected from the field test was taken to IHP's corporate headquarters in Maryland where it was entered and stored in a Data General mainframe computer. This extensive set of data was later transferred to magnetic tape and taken to the University of Maryland for analysis.

The statistical procedures conducted on the Marine Corps data included: descriptive statistics which detail physical characteristics of the subjects as well as performance times for each phase of the field test, correlational statistics which describe the degree of relationship between the fitness variables and field performance tasks, and a multiple regression analysis which aided in selecting measures to be used in a test battery designed to predict physical performance (23). The following discussion enumerates each of the statistical applications and describes the data included in each table.

Descriptive Statistics

Descriptive Statistics illustrating the Marine Corp sample demographically as well as by their performance are presented in the following tables. Each table contains the mean, standard - deviation (Std. Dev.) and the range for each variable. Table 1 defines the population under study with respect to physical and physiological parameters, including age, height, weight, lean body weight (LBW), percent fat, and maximum oxygen uptake ($\dot{V}O_2$)*. Tables 2 and 3 show the performance of this population on the Marine Corps PFT and on the selected test battery, respectively. These measures include the 3-mile run, situps, pullups/chinups, 150-yard dash, pullups with a pack, and the longjump. Data describing performances on the criterion measure or field test are presented in Table 4. Performances on the field test are quantified by the amount of time taken to perform each task. Times are presented for each event and for the entire scenario. Data are also presented indicating the level of perceived exertion (PE), and average heart rate, allowing estimates to be drawn about the levels of output or exertion during the test.

Correlational Analysis

A linear correlational analysis was performed to determine the degree of relationship between each of the fitness measures (PFT and Test Battery) and the field performance times. This statistic was employed to provide evidence for or against the first hypothesis proposed in this manuscript. Each of the correlational coefficients (r) that were statistically significant at the .05 probability level have been reported in Table 5. Included with the

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*Oxygen uptake was predicted from the graph in Appendix A correlational coefficient is the coefficient of determination (r^2), which indicates the amount of common variance accounted for by the relationship, thereby giving some insight to the practical significance of a correlation. It is assumed that other sources of variance are due to chance, sampling errors, or differences in skill and effort put forth by the subjects.

Appendix B provides a chart of intercorrelations for each of the fitness variables and each of the field tasks. The correlational coefficients (r) and the significance levels (p) have been provided so that the relationships between tests and tasks can be ascertained.

Multiple Regression Analysis

Treatment of the data with a stepwise multiple regression analysis revealed several combinations of fitness variables capable of predicting field performance. This statistical procedure addresses the second hypothesis proposed by systematically summing groups of variables with increase predictive value and dropping variables not contributing to the relationship. Table 6 presents several of the more significant combinations of fitness variables and their respective correlational coefficients (R) as related to time. Squaring the multiple coefficient (R^2) gives the coefficient of determination indicating how much variance is due to the relationship. The table also provides the reader with data pertaining to the *F*-ratio, the statistical significance, and the degree of freedom (d.f.) associated with each step.

Although lacking practical significance, the regression correlation between anthropometric measures and total time ($R = .15$) is presented in response to the subproblem posed at the beginning of the study. The other correlations do have some practical significance and provide some prediction of performance.

Table 1. Characteristics of the Marine Corps Sample.

N=199

	Mean	Std.Dev.	Range
Age: (Years)	22.7	1.7	18 - 36
Height: (Inches)	69.2	2.6	63 - 76
Weight: (Pounds)	169.6	22.6	116 - 285
LBW: * (Pounds)	146.3	17.3	102 - 252
Percent Fat:	13.5	4.1	4.1 - 26.5
$\dot{V}O_2$: (ml/kg/min)	57.0	7.0	36 - 73

*LBW = Lean Body Weight

Table 2. Performance data for the Marine Corps PFT.

N=199

	Mean	Std.Dev.	Range
3-mile run: (min.)	22.2	2.3	16 - 30
Situps:	73.6	13.1	35 - 99
Pullup/Chinup:	10.4	4.9	0 - 31
PFT scores:*	211.0	40.2	113 - 300

*Maximum score is 300

Table 3. Performance data for Test Battery

N=199

	Mean	Std.Dev.	Range
150-yard dash: (sec.)	23.3	2.2	19 - 33
Pullup w/ pack:	2.5	2.7	0 - 15
Longjump: (feet)	7.3	0.8	5.4 - 12.8

Table 4. Performance data for Criterion Measure.

N=199

	Mean	Std.Dev.	Range
VB Time: (min)	15.3	2.5	9 - 25
Pack Time: (min.)	45.8	11.8	28 - 99
Akhio Time: (min.)	36.9	11.3	21 - 103
Dig Time: (min.)	17.2	5.7	5 - 43
Sprint Time: (sec.)	28.9	5.3	20 - 56
Total Time: (min.)	115.8	24.3	74 - 204
Perceived Exertion:	15	2.2	7 - 20
Avg. H.R.: (bpm)	157	10.6	128 - 183

---

1. Perceived Exertion; scale of 7 to 20 (29)
   (7 very, very light - 20 very, very heavy)

2. Average Heart Rate; the mean of 157 = 70% of $\dot{V}O_2$ max (26).

Table 5. Relationships between fitness variables and performance.

N=199

Fitness Variables

	Situps	3-mile run	Pullups	150-yard dash	Pullup w/pack	Long jump
Performance Times						
V.B.:	-.40*	-.65**	-	-.45**	-	-
Pack:	-.52**	.59**	-	-	-.39*	-
Akhio:	-.56**	.51**	-	-	-	-
Dig:	-.44**	-	-	-	-	-
Dash:	-.41*	.41*	-.43**	-.69**	-.41*	-.54**
Total:	-.58**	.61**	-	.42**	-	-

* p< .05

** p< .01

Table 6. Multiple Regression Analysis of various test combinations to total time.

Regression A. Total Time Against Anthropometric Measures.

Predictor	R	R^2	d.f.	F
Step 1 weight:	.15	.02	1,198	4.83*

Note: Only variable 'weight' met significance level for entry.
: 13 observations deleted due to missing values.

* p< .05

Regression B. Total Time Against Physical Performance Measures.

Predictor	R	R^2	d.f.	F
Step 1 3-mile run:	.37	.13	1,197	30.41**
Step 2 situps:	.43	.19	2,196	22.43**
Step 3 pullups:	.43	.21	3.195	16.84**
Step 4 pack pullup:	.49	.24	4,194	15.11**

Note: 13 observations deleted due to missing values.

** p< .01

Table 6. Regression Analysis continued.

Regression C. Total Time Against Physical Performance and Anthropometrics.

Predictor	R	R^2	d.f.	F
Step 1 3-mile run:	.36	.13	1,179	26.34**
Step 2 waist circumference:	.42	.18	2,178	19.46**
Step 3 situps:	.46	.21	3,177	15.80**
Step 4 hilldash:	.48	.23	4,176	13.18**

Note: 31 observations deleted due to missing values.

** $p < .01$

Regression D. Total Time Against Physical Performance.

Predictor	R	R^2	d.f.	F
Step 1 hilldash:	.28	.08	1,162	14.00**
Step 2 3-mile run:	.42	.18	2,161	17.71**
Step 3 situps:	.45	.20	3,160	13.54**
Step 4 pullups:	.47	.22	4,159	11,13**
Step 5 pack pullups:	.48	.23	5,158	9.69**

Note: 48 observations deleted due to missing values.

** $p < .01$

Table 7. Relationships of LBW, Percent Fat, and Fitness Levels (PFT) to Field Performance (time).

	LBW	% Fat	PFT
Total Time:	-.39*	-	-.55**
V.B. Time:	-	-	-.50**
Pack Time:	-	-	-.53**
Akhio Time:	-.46**	-	-.47**
Dig Time:	-	-	-.39*
Dash Time:	-	.47**	-.51**

* p< .05

** p< .01

Discussion

Subjects

The Marine Corps men in the sample ranged in age from 18 to 36 years. They were, on the average, heavier, shorter, had less body fat and higher $\dot{V}O_2$'s than their age-matched counterparts outside the military (24, 25). Some of these differences may be due in part to self-selection and training. For example, because Marines actively seek fit young recruits and expose them to regular physical activity they may loose fat, gain muscle mass and increase $\dot{V}O_2$.

Fitness Variables

Marine performances on the fitness tests reflected the relatively high level of fitness of this group (Tables 2 and 3). When the mean scores from the 3-mile run, situps, pullups/chinups, and the longjump are compared to the norms for college students, the Marine sample consistently scored in the 90th percentile (26, 27). Because the 150-yard dash and pullups with a pack are such new tests, no comparative data was available. Based on the trends already established, however, we might expect the Marines' scores to be higher than their age-matched counterparts.

Work Performance

Table 4 presents the times for the criterion measure. When reviewing these performances several compounding variables must be taken into consideration: One of the most immediately recognized handicaps was the altitude; the test was conducted at an altitude of nearly 9000 feet above sea level. Because of the decreased partial pressures of gases at this altitude, oxygen transport is reduced by more than 15% (28). This reduction limits the functional aerobic capacity of each participant. Another limiting factor was the heavy clothing that Marines are required to wear. For example, the vapor barrier (Mickey Mouse) boots weigh over five pounds a pair and, while providing exceptional warmth, they can severely restrict mobility. A third factor which can limit performance is motivation. Test administrators noted that although most subjects put forward a good effort, some merely strolled through the entire exercise. This behavior not only lengthens times but weakens relationships between fitness tests and performance. Attempts were made to limit motivational problems by stressing the importance of each subject giving his best effort and by awarding each finisher a commemorative T-shirt. These measures, however, did not motivate everyone and a number of participants maintained their slow pace. Equipment problems also caused delays for a number of subjects. The most prevalent malfunction was snowshoe bindings that wouldn't securely hold the vapor barrier boots. In many cases the loose bindings would trip the Marine causing him to fall into deep snow with the heavy pack. Finally there was the effect of changing snow conditions encountered each day. Early in the day the groomed trails would be icy and fast; however, as the sun warmed the snow, it became softer and slower. The net effect was that those subjects who began the field test earlier in the day had more favorable snow conditions than those who started later. These changing conditions may have weakened the relationships between the tests and performance.

The data in Table 4 shows that the subjects averaged 115 minutes on the scenario and that the average heart rate was 157 beats per minute. Most of the Marines perceived the workload to be "heavy" on a scale of 7 to 20, where 7 is very, very light and 20 is very, very heavy (29). This data suggests that the average Marine spent nearly two hours working at a continuous heavy workload, interrupted only by brief rest/rehydration periods. Given the heart rate data, the average Marine worked at 70% of his $\dot{V}O_2$ max.

Relationship of Fitness to Performance

The results of the correlational analysis presented in Table 5 show the relationship of the individual fitness variables to work performance expressed as time. Critical or statistically significant values for the linear coefficient (r) are .139 for the .05 significance level, and .182 for the .01 significance level (N = 200) (30). As indicated on the chart, pullups with a pack, and the longjump are not related to total time, but situps, the three-mile run, and the 150-yard hill dash are. The situps and 3-mile run are of particular significance; both are components of the PFT and both are highly related to work performance. (The negative correlation with situps is due to the fact that as fitness levels and the number of situps increase, performance time decreases).

The PFT is well correlated to both total performance and the individual performance segments. Because pullups are not correlated to performance, the 3-mile run and situps are better indicators of performance than the PFT as a whole. Nonetheless, the PFT is significantly correlated to work in this environment.

Two additional findings are the weak correlations noted with LBW and percentage Fat as compared to total work time. LBW is statistically correlated to work performance (r = -.39), but the practical significance of this relationship is weak. The coefficient of determination (r^2) indicates that only fifteen percent of the variance is due to this relationship, while eighty-five percent of the variance is due to other factors. Percent fat is not related to total work performance. While these results fit the hypothesis, they do not agree with the results of Sharkey (1980) and

Dotson (1976) which were presented in the first chapter. These anomalies may be attributed to other factors such as motivation, altitude, and also the fact that we are dealing with a limited range with respect to these parameters. For example, as Table 1 indicates, the Marine population is lower in fat and higher in LBW than many non-military populations such as those cited above. The limited range of scores may weaken on the correlations to performance.

Multiple Regression Analysis

The results of the multiple regression analysis conducted to select items for possible inclusion in a field test are given in Table 6. This statistical tool has provided several combinations of fitness variables offering the test administrator several options as to which group to utilize. The choice of test combinations will depend on a number of factors including the ease of administration and the costs associated with the test.

Appendix B provides a comprehensive listing of intercorrelations for each of the fitness variables and performance measures from the field event. This chart of correlational coefficients allows one to assess the amount of common variance that exists between tests and between tasks. This assessment can aid the reader when interpreting the multiple correlational coefficients.

Analysis of the intercorrelations reveals that some of the fitness tests have elements in common. For example, the 3-mile run has approximately 34 percent variance in common (r^2) with each of the fitness measures except the longjump. Another example of common variance is the 85 percent that pullups and pullups with a pack have in common. When two or more variables have a great deal of common variance, computer generated multiple regression analyses may choose one variable to represent several parameters. The reader should note that in the regression analysis presented in Table 6, both pullups and pullups with pack were included together - apparently the 15 percent that they shared on intercorrelations accounted for an additional 3 percent variance in the multiple correlation.

Inspection of the intercorrelations between field performance times indicates that they share elements in common as well. For example, V.B. time, pack time, AKHIO time, dig time, and dash time are all highly correlated to total time (r = .78, .92, .92, .73, .67 $p < .01$). Furthermore, intercorrelations between the aerobic events (V.B., showshoes with pack, and AKHIO pull) indicate that they minimally have 48 percent variance in common (r = .69), whereas these measures have at most 31 percent variance in common with the anaerobic event (resupply dash, $p < .01$). These differences point out that there are several components to account for when predicting field performance.

The regression analysis will select combinations of variables that are correlated to each of the components represented by total time. For example, total time is composed in part by V.B. time, pack time, and AKHIO time which are all aerobic events and highly correlated to the 3-mile run (.65, .59, .51 $p< .01$) and situps (-.40, -.52, -.56 $p< .05$). We also find that V.B. time and AKHIO time are related to the 150-yard dash (.45, .36 $p< .01$) suggesting an anaerobic component to performance. Further inspection of Appendix B reveals that pack time is related to pullups with pack (.39 $p< .05$) indicating that, perhaps, shoulder strength and the ability to carry the load was a factor in this event. The analyses in Table 6 detail those fitness measures best able to account for the variance associated with the dependent variable total time. As can be inferred from the intercorrelations, the 3-mile run and situps are included in each regression equation, except the equation based solely on anthropometric measures. In each equation (Table 6; B, C, D) these two variables account for a large part of the aerobic component of performance. Additionally, equations B and D use pullups and pullups with a pack to account for other components such as upper body strength and endurance. Equations C and D both utilize the 150-yard dash to account for an anaerobic component. In summary, using the chart of intercorrelations in conjunction with the multiple regression equations, allows inferences between fitness measures and performance components to be drawn. This not only provides a test capable of predicting performance, but also can help guide the development or refinement of training programs.

Contrary to what was hypothesized, the multiple correlational coefficients generated from this data did not yield correlations as strong as those obtained for some of the individual fitness measures (as in Table 5). For example, multiple regression coefficients for tests B, C, and D are R=.49, .48 and .48 respectively, while the 3-mile run has a linear coefficient of r=.61 and situps have been shown to correlate to total time with a value of r= -.58. (Both values are significant at the p< .001 level). The weaker correlational coefficients associated with the multiple regression are apparently related to the fact that in each case a substantial number of subjects were deleted due to missing values. The number of entries omitted by the program ranged from 13 to 48 for the regressions presented. This large number of deletions constitutes nearly one-fourth of the sample, with many of the cases suspected of being at the extremes of the range. The net effect of reducing the range is a weakened correlational coefficient. The subjects with missing values included those who were injured while training with the Marine Corps, were injured in the field test, were ill on the test day and were not rescheduled for another day, ran out of time while taking the test, or failed to complete the PFT or test battery while at the Marine base in San Diego. Based on other studies using similar statistical procedures (3, 4, 6, 8, 9, 20, 23, 26, 31), one may reason that, had these missing values been present, the multiple correlations would have been significantly higher.

Because the multiple correlational coefficients and amount of variance accounted for by each of the regression equations (B, C, D) are so similar, the choice of which test to utilize will depend on administrative and budgetary considerations. Equations B and C are preferable to D because D requires an additional measure without increasing predictive ability. Beyond this point, the facilities available should guide text selection. For example, if a gradual hill (5%-grade 150 yards) is available, use equation C. If no hill is available, locate a chinup bar and a 30-pound pack and use test B. Each will account for nearly 24 percent of the variance when trying to assess a Marines' physical readiness to perform in the Winter Mountain Warfare Environment.

CHAPTER IV

Summary, Conclusion and Recommendations

The purpose of this study was to determine if performance on the PFT or other selected tests allowed prediction of performance in actual field tasks. The subproblem was to determine if LBW and percent fat were predictors of field performance. Based on the findings presented in Chapter III, performance on the PFT and other selected tests allows one to predict field performance. This statement must be qualified, however, to point out that not all of the items in the test battery or PFT are related to field performance (i.e.: pullups, pullups with pack, longjump and percent fat are not). Furthermore, LBW is statistically correlated to performance, yet it lacks practical significance. Percent fat is not predictive of field performance in this study.

Based on the findings, the first hypothesis was rejected. Some of the fitness variables (3-mile run, situps, 150-yard dash, LBW, and the PFT) are significant predictors of performance time in the Winter Mountain Warfare field events. The second hypothesis of this study can be accepted; a multiple regression analysis with selected combinations of fitness variables is predictive of performance in the Winter Mountain Warfare Scenario.

Due to the deletion of a substantial number of data sets, the reader should acknowledge that the multiple correlational coefficients have been compromised. Given the full range of scores, these values could be expected to be more predictive of performance than individuals tests.

In conclusion, performance on the PFT is indicative of performance in the Mountain Warfare Environment. Furthermore, based on the results of this study, most of the variables in the test battery are not correlated to field performance. Other conclusions that can be drawn include the finding that our assumptions may be invalid. For example, it was assumed that performances on the PFT, Test Battery, and Field Test were products of maximal effort, however, the observations of the test administrators indicate that not all subjects performed maximally. Moreover the effect of the changing snow conditions, equipment problems, and the effects of altitude combined with motivational problems to limit field performance times. These limitations, many of them unforeseen, must be addressed in future studies of this type.

Future studies attempting to predict work performance from fitness measures should consider the following recommendations:

1. If using LBW or Percent Fat in a sample with a limited range, use an analysis of variance to see if the extreme values of these measures are significantly different in terms of performance.

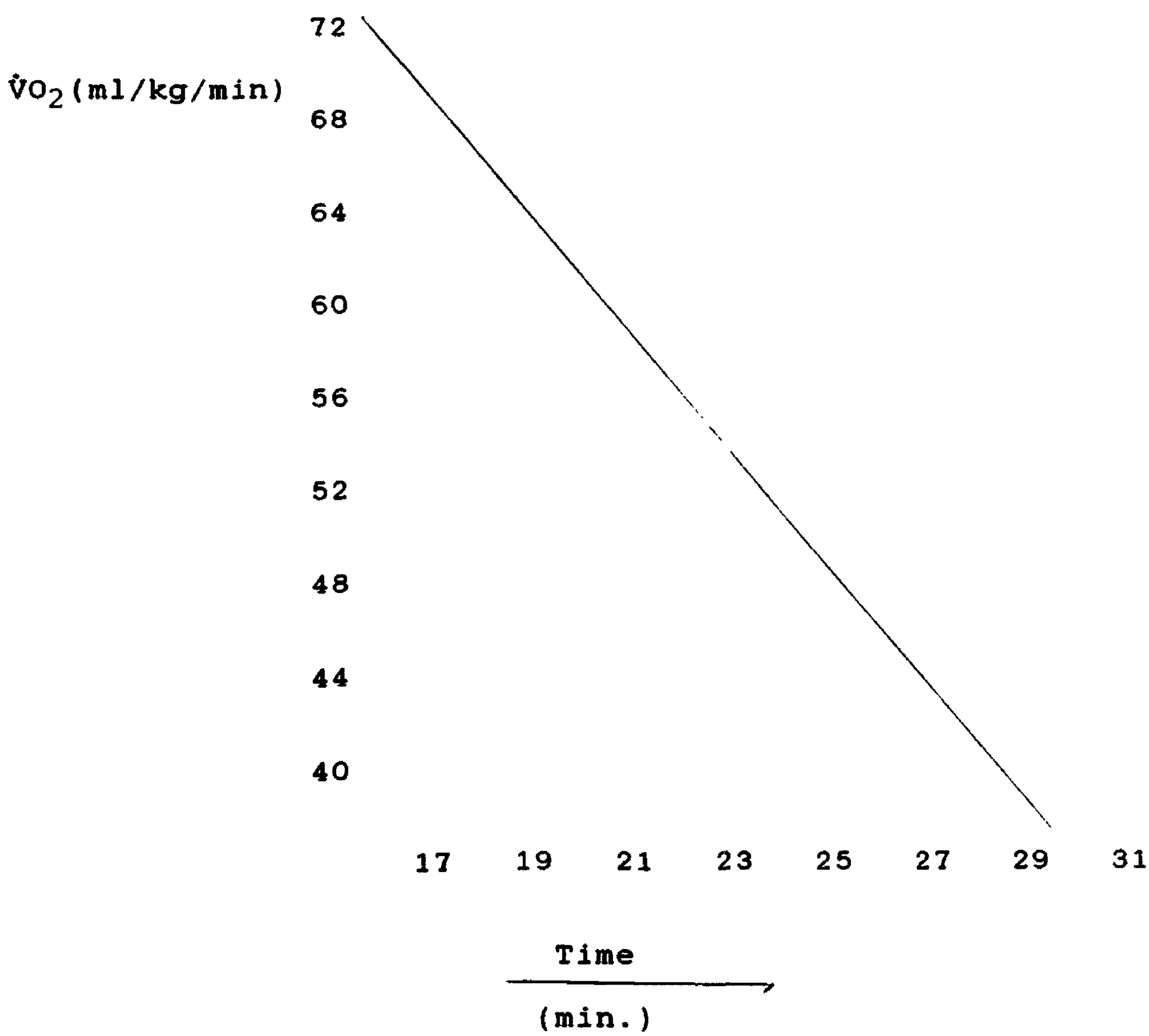
2. Try to ensure similar test conditions for each subject. In the Winter Mountain Warfare scenario this may

entail using the snow course for only a few hours each morning.

3. Stress the importance of each participant giving his best effort. Perhaps a reward for good performances would help prevent people from walking through the exercise.

APPENDIX A

Max $\dot{V}O_2$ Vs. 3-mile run time.*



* From Naval Medical Field Research Lab (12)

APPENDIX B

Intercorrelations

	1	2	3	4	5	6	7
1. 3-mile run:		-.58*	-.62*	-.83*	-	-.57*	.55*
2. Situps:			.51*	.83*	-	.45*	-.51*
3. Pullups:				.89*	.49*	.92*	-.63*
4. PFT:					.47*	.81*	-.70*
5. Longjump:						.48*	-.76*
6. Pack pullup:							-.60*
7. Hill Dash:							
8. Neck Circumference:							
9. Waist Circumference:							
10. Weight:							
11. Height:							
12. % Fat:							
13. LBW:							
14. V.B. Time:							
15. Pack Time:							
16. Akhio Time:							
17. Dig Time:							
18. Dash Time:							
19. Total Time:							
20. Average Heart Rate:							
21. Perceived Exertion:							

N = 199
* r> .18 significant at p< .01
** r> .14 significant at p< .05

APPENDIX B

Intercorrelations

	8	9	10	11	12	13	14
1. 3-mile run:	-	-.52*	-.46*	-	.45*	-.39**	.65*
2. Situps:	-	-	-	-	-	-	-.40**
3. Pullups:	-	-.66*	-.49*	.44*	-.69*	-	-
4. PFT:	-	-.62*	-.42**	-	-.64*	-	-.50*
5. Longjump:	-	-.48*	-	.41**	-.60*	.44*	-
6. Pack pullup:	-	-.57*	-	-	-.63*	-	-
7. Hill Dash:	-	-	-	-	.69*	-.37**	.45*
8. Neck Circumference:		-	-	-	-	-	-
9. Waist Circumference:			.85*	.56*	.92*	.68*	-
10. Weight:				.72*	.69*	.96*	-
11. Height:					.45*	.71*	-
12. % Fat:						-	-
13. LBW:							-
14. V.B. Time:							
15. Pack Time:							
16. Akhio Time:							
17. Dig Time:							
18. Dash Time:							
19. Total Time:							
20. Average Heart Rate:							
21. Perceived Exertion:							

N = 199
* r> .18 significant at p< .01
** r> .14 significant at p< .05

APPENDIX B

Intercorrelations

	15	16	17	18	19	20	21
1. 3-mile run:	.58*	.51*	-	.41**	.61*	-	-
2. Situps:	-.52*	-.56*	-.44*	-.41**	-.58*	.45*	-
3. Pullups:	-	-	-	-.42**	-	-	-
4. PFT:	-.53*	-.47*	-.39**	-.45*	.55*	.33**	-
5. Longjump:	-	-	-	-.54*	-	-	-
6. Pack pullup:	-.39**	-	-	-.41**	-	-	-
7. Hill Dash:	-	.36*	-	.69*	-.70*	-	-
8. Neck Circumference:	-	-	-	-	-	-	-
9. Waist Circumference:	-	-.45**	-	-	-.62*	-	-
10. Weight:	-	-.48*	-	-	-.42**	-	-
11. Height:	-	-.48*	-	-	-.39**	-	-
12. % Fat:	-	-	-	.47*	-	-	-
13. LBW:	-	-.46*	-	-	-.39**	-	-
14. V.B. Time:	.73*	.69*	.50*	.69*	.78*	-	-
15. Pack Time:		.74*	.52*	.64*	.92*	.51*	-
16. Akhio Time:			.56*	.56*	.92*	-.49*	.40**
17. Dig Time:				-	.73*	-	-
18. Dash Time:					.67*	-.39**	-
19. Total Time:						.53*	-
20. Average Heart Rate:							-
21. Perceived Exertion:							

N = 199
* r> .18 significant at p< .01
** r> .14 significant at p< .05

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